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## **Alternative Transportation Fuels and Vehicles: Energy, Environment, and Development Issues**

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# Alternative Transportation Fuels and Vehicles: Energy, Environment, and Development Issues

## Summary

The sharp increase in petroleum prices beginning in mid-1999, experiences with tighter supply, and international instability have renewed concern about our dependence on petroleum imports. One of the strategies for reducing this dependence is to produce vehicles that run on alternatives to gasoline and diesel fuel. These alternatives include alcohols, gaseous fuels, renewable fuels, electricity, and fuels derived from coal. The push to develop alternative fuels, although driven by energy security concerns, has been aided by concerns over the environment, because many alternative fuels lead to reductions in emissions of toxic chemicals, ozone-forming compounds, and other pollutants, as well as greenhouse gases.

Each fuel (and associated vehicle) has various advantages and drawbacks. The key drawback of all alternative fuels is that because of higher fuel and/or vehicle prices, alternative fuel vehicles (AFVs) are generally more expensive to own than conventional vehicles. And while many AFVs have superior environmental performance compared to conventional vehicles, their performance in terms of range, cargo capacity, and ease of fueling may not compare favorably with conventional vehicles. Furthermore, because there is little fueling infrastructure (as compared to gasoline and diesel fuel), fueling an AFV can be inconvenient.

Any policy to support AFVs must address the performance and cost concerns, as well as the issue of fueling infrastructure. Within this context, a “chicken and egg” dilemma stands out: The vehicles will not become popular without the fueling infrastructure, and the fueling infrastructure will not expand if there are no customers to serve.

Three key laws, the Alternative Motor Fuels Act of 1988 (P.L. 100-494), the Clean Air Act Amendments of 1990 (P.L. 101-549), and the Energy Policy Act of 1992 (P.L. 102-486), as well as three Executive Orders, support the development and commercialization of alternative fuels and alternative fuel vehicles. These legislative acts and administrative actions provide tax incentives to purchase AFVs, promote the expansion of alternative fueling infrastructure, and require the use of AFVs by various public and private entities.

The 108<sup>th</sup> Congress considered comprehensive energy legislation, but a final bill was not submitted to the President for signature. H.R. 6 would have promoted the development of renewable fuels, especially ethanol and hydrogen. Further, it would have provided incentives for the development and purchase of alternative fuel and advanced technology vehicles. In addition to the energy bill, other bills were introduced to create vehicle purchase tax credits, promote research and development of fuels, and require the use of alternative fuels. It is likely that similar legislation will be introduced in the 109<sup>th</sup> Congress.

This report reviews these issues. It will be updated as events warrant.

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# Alternative Transportation Fuels and Vehicles: Energy, Environment, and Development Issues

## Introduction

Is there any practical replacement for gasoline and diesel fuel in automobiles? Since the oil crises of the 1970s and the rise in the awareness of environmental and security issues, policy makers have often considered this question. For many reasons, the United States has searched for alternatives to petroleum fuels. These reasons include limiting dependence on imported petroleum, controlling the emissions of pollutants into the air, and limiting the emissions of greenhouse gases.

Several fuels are considered alternative transportation fuels by the federal government. These fuels are electricity, natural gas, propane (liquefied petroleum gas, or LPG), ethanol, methanol, biodiesel, and hydrogen. Some of these fuels are similar to conventional fuels, and can be used in conventional vehicles with little or no modification to the vehicle. However, some of these fuels are significantly different, and require the use of completely different engine, fuel, and drive systems. Consequently, cost as well as performance of the associated alternative fuel vehicles (AFVs) must be part of the discussion. Key factors in the ultimate success or failure of any alternative fuel include the relative cost of the fuel, the ability to develop and expand fueling stations, and the performance and safety of the fuel.

For various reasons — notably cost, performance, and availability — alternative fuels have yet to play a major transportation role in the United States. Many argue that the government must step in. Congress, recent Administrations, and state governments have instituted some key programs to promote the use of alternative fuels. These programs include tax incentives for the purchase of alternative fuels and alternative fuel vehicles (AFVs), purchase requirements for government and private fleets, and research grants for the study of alternative fuels. Despite these efforts, only about 480 million gallons<sup>1</sup> of alternative fuels were consumed in 2004, just 0.3% of motor fuel demand (136 billion gallons of gasoline and 36 billion gallons of diesel).<sup>2</sup>

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<sup>1</sup> This does not include ethanol blended in gasoline, which constitutes approximately 1% of the volume of motor gasoline in the United States.

<sup>2</sup> U.S. Department of Energy, Energy Information Administration (EIA), *Alternatives to Traditional Transportation Fuels 2003*, December 2004.

## Legislative Background

The three most important statutes concerning alternative fuels are the Alternative Motor Fuels Act of 1988 (AMFA, P.L. 100-494), the Clean Air Act Amendments of 1990 (CAAA, P.L. 101-549), and the Energy Policy Act of 1992 (EPAAct, P.L. 102-486). AMFA promoted federal government use of alcohol- and natural gas-fueled vehicles. EPAAct requires that federal and state agencies, as well as private firms that distribute alternative fuels, must purchase for their fleets a certain proportion of vehicles that are capable of being fueled by specific non-petroleum fuels. Furthermore, EPAAct grants the Department of Energy (DOE) the authority to make similar requirements of local governments and private fleets. In addition, EPAAct provides tax incentives for private purchases (both individual and commercial) of AFVs. CAAA requires government and private fleets in cities with significant air quality problems to use low-emission, “clean-fuel” vehicles.

In addition to these laws, recent executive orders have also shaped alternative fuels policy in the United States. These include E.O. 12844, which urged federal agencies to exceed EPAAct purchase requirements; E.O. 13031, which required that federal agencies meet EPAAct requirements regardless of budget; and E.O. 13149, which aims to drastically reduce federal government petroleum consumption through the use of AFVs and hybrid vehicles. The major alternative fuels legislation and relevant Executive Orders are summarized in Table 1 and discussed further below.

**Table 1. History of U.S. Alternative Fuel Vehicle Policies**

Policy	Year	Key Provisions
Alternative Motor Fuels Act (42 U.S.C. 6374)	1988	<ul style="list-style-type: none"> <li>— Promoted Federal Government acquisition of AFVs</li> <li>— Established commercial demonstration programs for alternative fuel heavy-duty trucks</li> </ul>
Clean Air Act Amendments (42 U.S.C. 7581)	1990	<ul style="list-style-type: none"> <li>— Established Clean Fuel Fleet Program</li> </ul>
Energy Policy Act (42 U.S.C. 6374)	1992	<ul style="list-style-type: none"> <li>— Established AFV purchase requirements for Federal, state, and fuel provider fleets</li> <li>— Established tax incentives for the private purchase of AFVs</li> </ul>
Executive Order 12844	1993	<ul style="list-style-type: none"> <li>— Urged agencies to exceed requirements set in EPAAct</li> </ul>
Executive Order 13031	1996	<ul style="list-style-type: none"> <li>— Required federal agencies to meet EPAAct requirements regardless of budget</li> <li>— Required yearly progress reports on EPAAct purchases</li> </ul>
Executive Order 13149	2000	<ul style="list-style-type: none"> <li>— Set goal of reducing federal government petroleum consumption</li> <li>— Identified several strategies, including the use of AFVs and hybrid vehicles</li> </ul>

## The Alternative Motor Fuels Act of 1988

Beginning in FY1990, the Alternative Motor Fuels Act called for the federal government to acquire the “maximum practicable” number of light-duty alcohol and natural gas vehicles. In addition, AMFA established an Interagency Commission on Alternative Motor Fuels to develop a national alternative fuels policy. The act also established a commercial demonstration program to study the use of alcohol and natural gas in heavy duty trucks. Since 1991, DOE has supported projects in these areas, making the data publicly available through its Alternative Fuels Data Center (AFDC).<sup>3</sup>

## The Clean Air Act Amendments of 1990

The Clean Air Act Amendments of 1990 established the Clean Fuel Fleet Program (CFFP).<sup>4</sup> This program requires cities with significant air quality problems to promote vehicles that meet clean fuel emissions standards. In metropolitan areas in extreme, severe, or serious non-attainment for ozone<sup>5</sup> or carbon monoxide, fleets of 10 light-duty vehicles or more face purchase requirements similar to those for EPAct (discussed below). However, under CFFP, conventional vehicles are admissible if they meet National Low Emission Vehicle (LEV) standards. Another key difference between the CFFP requirements and the EPAct requirements is that under CFFP, a vehicle must always be operated on the fuel for which it was certified. For example, if a dual-fuel ethanol vehicle is certified LEV using ethanol, but not using gasoline, the vehicle must be operated solely on ethanol. This provision avoids a perceived “loophole” in EPAct.

## The Energy Policy Act of 1992

The Energy Policy Act of 1992 was enacted to promote energy efficiency and energy independence in the United States. It includes programs that require or promote alternative fuel vehicles, as well as commercial and domestic energy efficiency, natural gas imports, and nuclear power. Two key programs concerning alternative fuels are the AFV purchase requirements for federal, state, and alternative fuel provider<sup>6</sup> fleets, and the AFV tax incentives.

**Fleet Requirements.** EPAct<sup>7</sup> requires that a certain percentage of new light-duty vehicles (passenger cars and light trucks) purchased for certain fleets must be

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<sup>3</sup> [<http://www.eere.energy.gov/cleancities/afdc/>].

<sup>4</sup> P.L. 101-549, section 246.

<sup>5</sup> Ozone standards are maintained by limiting emissions of the three key components of ozone: nitrogen oxides (NOx), volatile organic compounds (VOCs), carbon monoxide.

<sup>6</sup> An alternative fuel provider fleet is a fleet of vehicles owned and operated by a private company that sells or distributes alternative fuels.

<sup>7</sup> P.L. 102-486, sections 303, 501, and 507.

fueled by an alternative fuel.<sup>8</sup> Covered fleets are those that operate 50 or more light-duty vehicles, of which at least 20 operate primarily in a metropolitan area. Furthermore, the fleets must be capable of being fueled at a central location, such as the fleet motor pool. Law enforcement vehicles, emergency vehicles, combat vehicles, non-road vehicles, and vehicles used for testing are exempted from the requirement. Federal, state, and alternative fuel provider fleets are currently required to purchase AFVs. The purchase requirements were phased in between 1997 and 2001. (See **Table 2.**) DOE was required to consider whether to include municipal and private fleets in the program, but recently determined that such a requirement would not significantly reduce energy dependence.<sup>9</sup>

**Table 2. Light-Duty Alternative Fuel Vehicle Purchase Requirements under the Energy Policy Act**

Year	Percentage of all Acquisitions for Covered Fleets		
	Federal	State	Alternative Fuel Provider
1997	33%	10%	30%
1998	50%	15%	50%
1999	75%	25%	70%
2000	75%	50%	90%
2001 and beyond	75%	75%	90%

**Source:** National Alternative Fuels Hotline, Department of Energy, September 1998.

DOE currently recognizes the following as alternative fuels: methanol and denatured ethanol as alcohol fuels (mixtures that contain at least 70% alcohol), natural gas (compressed or liquefied), liquefied petroleum gas (LPG), hydrogen, coal-derived liquid fuels, fuels derived from biological materials, and electricity.<sup>10</sup> Covered vehicles may be dedicated<sup>11</sup> or dual fuel.<sup>12</sup>

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<sup>8</sup> EPAct defines an alternative fuel as “any fuel the Secretary [of Energy] determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits.”

<sup>9</sup> 69 *Federal Register* 4219.

<sup>10</sup> Some fuels may actually be covered by more than one category. For example, most ethanol (an alcohol fuel) is derived from corn or other agricultural products (biological materials).

<sup>11</sup> Dedicated: operated solely on an alternative fuel.

<sup>12</sup> Dual-fuel: capable of being operated on both conventional and alternative fuel. There are two types of dual-fuel vehicles, bi-fuel and flexible fuel. Bi-fuel vehicles can only be operated on one fuel at a time, while flexible fuel vehicles can operate on any mixture of the two fuels.



There have been mixed results from the program. According to DOE, some federal and state agencies are exceeding their mandates, while others are far below their quota. As a whole, the federal government is was compliance in 1998, mainly due to large purchases such as 10,000 ethanol vehicles purchased by the U.S. Postal Service in that year.<sup>13</sup> However, according to a coalition of environmental groups, the government as a whole has failed to comply with EPO Act since then. In a suit filed by Earthjustice<sup>14</sup> in San Francisco federal court, 18 federal agencies are accused of failing to comply with the purchase requirements.<sup>15</sup> In July 2002, the court ruled that the federal government had violated EPO Act. Further, the court required the agencies to compile and make public, by January 31, 2003, reports on their non-compliance. Recently, the environmental groups filed a motion that the court find the agencies in contempt. Earthjustice argues that some agencies have failed to submit reports entirely and that others have submitted unsubstantiated reports.<sup>16</sup> In addition, questions have been raised about the success of the program since other covered fleets, especially fuel provider fleets, have not reported their purchases to DOE.<sup>17</sup>

A key concern over the fleet requirements is whether they actually support the goals of EPO Act. This is because EPO Act does not require the use of alternative fuels, only the purchase of AFVs. Fleets can purchase dual-fuel vehicles, operate them solely on gasoline or diesel fuel, and still meet the EPO Act requirements. The fleet program has been criticized because this use of dual-fuel vehicles is seen by some as a “loophole.” This criticism is another element of the lawsuit filed by Earthjustice.

**Tax Incentives.** Another key provision of EPO Act is a set of tax incentives for the purchase of new AFVs.<sup>18</sup> The act provides an electric vehicle (EV) tax credit of 10% of the purchase price, up to a maximum of \$2,000 in 2005. In addition, it provides a Clean Fuel Vehicle (any alternative fuel) tax deduction of up to \$1,000 in 2005 for light-duty vehicles, with larger deductions for heavier vehicles. Vehicles are not eligible for both incentives, and vehicles purchased to meet mandated fleet requirements are ineligible for either incentive. The EV tax credit and the Clean Fuel Vehicle tax deduction are being phased out, and are scheduled to reach zero after 2006.

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<sup>13</sup> In 1998, the U.S. Postal Service placed an order with Ford for 10,000 specially-designed Ford Explorers. The redesigned sport-utility vehicles use flexible fuel ethanol/gasoline engines.

<sup>14</sup> Earthjustice is representing the Sierra Club, the Center for Biological Diversity, and the Bluewater Network.

<sup>15</sup> “U.S. Agencies Sued on Alternative Fuel Rule,” *San Francisco Chronicle*. January 3, 2002. p. A3.

<sup>16</sup> Rachel Gantz, “Groups File Motion to Find U.S. Gov’t in Contempt of Alt Fuel Law,” *Oxy-Fuel News*. April 7, 2003.

<sup>17</sup> U.S. General Accounting Office (GAO), *Limited Progress in Acquiring Alternative Fuel Vehicles and Reaching Fuel Goals*. February 2000. p. 9.

<sup>18</sup> P.L. 102-486, section 1913.

## **Executive Orders**

Three Executive Orders have also played a key role in developing alternative fuels policies. Executive Order 12844, issued on April 21, 1993, urged federal agencies to make every effort to exceed the mandatory purchase requirements set in EPAct. The order argued that the federal government could provide impetus for the development and manufacture of alternative fuel vehicles, and the expansion of fueling stations and other infrastructure to support privately-owned AFVs.

Executive Order 13031, issued December 13, 1996, expanded the Administration's policy on EPAct fleets. The order required that federal agencies must comply with EPAct regardless of their budgets. The order also required that agencies must submit a yearly progress report to the Office of Management and Budget (OMB) along with their yearly budgets. Further, it established penalties for failing to meet the EPAct requirements. If an agency reported to OMB that it did not meet its EPAct requirements, that agency must submit a detailed plan for meeting the requirements the next year. The Order also established credits for the use of medium- and heavy-duty vehicles and EVs to meet the requirements.

Most recently, the Administration issued Executive Order 13149 on April 21, 2000. This order presents the goal of reducing the federal fleet's annual petroleum consumption by 20% below the FY1999 level by the end of FY2005. It suggests several strategies for attaining this goal, including using alternative fuel vehicles and high-efficiency hybrids. The order also requires that a majority of EPACT vehicles must be fueled with alternative fuels by FY2005. This helps fix the "loophole" that allows dual-fuel EPACT vehicles to operate solely on conventional fuel.

## **Alternative Fuels**

As noted above, several fuels are considered alternative fuels. This section will address alternative fuels recognized by EPAct. Many technical and market factors affect the usability and ultimate success of these fuels as alternatives to petroleum-based fuels. Since many of these fuels require entirely new engines, or extensive modifications to conventional vehicles, the characteristics of both alternative fuels and alternative fuel vehicles must be discussed together. Fuel cost and fueling infrastructure, vehicle cost, fuel and vehicle performance, and other factors for each fuel will be addressed in turn in the discussion below. Table 3 presents a summary of the various alternative fuels.

**Table 3. Summary of Alternative Fuels**

Fuel	Fuel Consumption (million GEG) <sup>a</sup>	Vehicles in Use	Fueling Sites <sup>b</sup>	Incremental Vehicle Cost <sup>c</sup>
LPG	242	194,000	3,451	\$1,000-\$2,000
Natural Gas	170	146,000	945	\$4,000-\$6,000
Biodiesel <sup>d</sup>	37	N/A <sup>e</sup>	177	—
Ethanol	22 <sup>f</sup>	146,000 <sup>g</sup>	205	\$0
Electricity	12	56,000	674	up to \$20,000
Methanol	0.3	4,600	0	\$500-\$2,000
Hydrogen	—	—	10	—
Coal-Derived Fuels	—	—	—	—

**Source:** Department of Energy and California Energy Commission.

**Notes:** All estimates are for 2004.

<sup>a</sup> GEG: Gasoline Equivalent Gallon. To compare various fuels, an equivalency factor is used. In this case, it is the amount of energy in one gallon of gasoline.

<sup>b</sup> As of December 3, 2004.

<sup>c</sup> This does not include additional infrastructure/fueling equipment costs or additional life-cycle vehicle costs (e.g. maintenance, resale).

<sup>d</sup> Since biodiesel can be blended with conventional diesel, separate refueling sites are not necessary.

<sup>e</sup> Biodiesel is used in conventional diesel engines.

<sup>f</sup> 1,813 million GEG including ethanol in blended gasoline.

<sup>g</sup> This does not include flexible fuel ethanol/gasoline vehicles that operate primarily or exclusively on gasoline. In 2002, there were approximately 4.1 million of these vehicles in the United States (Energy Information Administration estimate).

## Propane (LPG)

Liquefied petroleum gas (LPG) is produced as a by-product of natural gas processing and petroleum refining.<sup>19</sup> Because the components of LPG are gases at normal temperatures and pressures, the mixture must be liquefied for use in vehicles. In addition to vehicles, propane is also used in home heating as well as recreational activities.<sup>20</sup>

**Consumption.** LPG is the most commonly used alternative fuel. Domestic consumption was approximately 242 million gasoline equivalent gallons (GEG)<sup>21</sup> in

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<sup>19</sup> LPG is a mixture of hydrocarbons, mainly propane (C<sub>3</sub>H<sub>8</sub>), but also propylene (C<sub>3</sub>H<sub>6</sub>), butane (C<sub>4</sub>H<sub>10</sub>), and butylene (C<sub>4</sub>H<sub>8</sub>).

<sup>20</sup> Alternative Fuels Data Center (AFDC), *Propane (LPG) General Information*.

<sup>21</sup> Since all fuels have different energy contents, to compare performance factors (e.g. fuel economy and fuel cost) an equivalency factor is used. The most common factor is to determine the amount of alternative fuel needed to generate the energy in one gallon of gasoline. This amount is called a gasoline equivalent gallon (GEG). While some publications refer to this as a gasoline gallon equivalent (GGE), this report uses GEG throughout for clarity.

2004, or about 0.2% of gasoline demand.<sup>22</sup> This is greater than all other alternative fuels combined.<sup>23</sup> Propane is used in both light- and medium-duty vehicles, and there were approximately 194,000 LPG vehicles on the road in 2004,<sup>24</sup> or about 0.1% of the roughly 230 million gasoline and diesel-fueled vehicles.<sup>25</sup> In 2003, the federal government operated about 360 vehicles.<sup>26</sup> LPG vehicles tend to be custom vehicles; in fact, the only light-duty production vehicles with an LPG option are the Ford F150 pickup and the GM Express and Savanna vans (the latter two supplied by Quantum).<sup>27</sup>

**Cost.** On a GEG basis, fuel costs for LPG are approximately equal to those of gasoline, and tend to fluctuate with gasoline prices, although they can fluctuate more dramatically in response to high heating costs or other factors. Between April 2000 and October 2002, the price for LPG averaged approximately \$1.16 to \$1.95<sup>28</sup> per GEG. While fuel costs are only slightly higher for LPG as compared to gasoline, there is an incremental purchase cost for an LPG vehicle, which ranges between \$1,000 and \$2,000.<sup>29</sup> This additional cost covers modifications to the fuel system and the addition of a high-pressure fuel tank. Some of this incremental cost currently may be defrayed by federal, state, local, or manufacturer incentives that promote the purchase of alternative fuel vehicles.

**Infrastructure.** Because of its many uses,<sup>30</sup> the refueling system for LPG is extensive. There are approximately 3,500 refueling sites in all 50 states,<sup>31</sup> which corresponds to roughly 3% of the approximately 124,000 gasoline stations in the United States.<sup>32</sup> Because of its wide use, if the demand for LPG as an alternative fuel were to expand, it is likely that the supply infrastructure could expand proportionally.

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<sup>22</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

<sup>23</sup> Excluding ethanol in gasoline. When used as a blending agent, ethanol does not qualify as an alternative fuel.

<sup>24</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 1.

<sup>25</sup> U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 2001*. Table MV-1.

<sup>26</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 9.

<sup>27</sup> National Alternative Fuels Hotline, *Model Year 2002: Alternative Fuel Vehicles*. November 2001.

<sup>28</sup> U.S. Department of Energy, Clean Cities Program, *The Alternative Fuel Price Report*. 5/5/2000 through 12/27/2002. It should be noted that this price includes federal and state fuel excise taxes. In general, these taxes are lower for alternative fuels than for gasoline.

<sup>29</sup> California Energy Commission, *Liquefied Petroleum Gas / Propane-Powered Vehicles*. Updated March 10, 1999.

<sup>30</sup> Including home heating and outdoor grills.

<sup>31</sup> Department of Energy, Alternative Fuels Data Center (AFDC), *Refueling Sites*. [[http://www.eere.energy.gov/cleancities/afdc/infrastructure/station\\_counts.html](http://www.eere.energy.gov/cleancities/afdc/infrastructure/station_counts.html)]. Updated January 23, 2003.

<sup>32</sup> Department of Commerce, Bureau of the Census, *County Business Patterns for the United States*. [<http://www.census.gov/epcd/cbp/view/cbpview.html>].

LPG is delivered to retailers through a pipeline and tanker truck system much like the gasoline delivery system. Therefore, an expansion of the LPG supply infrastructure would face few technical barriers. However, because the fuel must be kept under pressure, special equipment is required to transfer LPG to a vehicle. Addition of new refueling equipment would lead to additional capital costs for retailers.

**Performance.** In terms of environmental performance, LPG vehicles tend to produce significantly lower ozone-forming emissions, although it can be difficult to quantify the differences. According to the California Energy Commission, LPG vehicles emit up to 33% fewer volatile organic compounds (VOCs), 20% less nitrogen oxides (NO<sub>x</sub>), and 60% less carbon monoxide.<sup>33</sup>

A key performance drawback to LPG is the somewhat decreased range as compared to gasoline. However, because LPG has the highest energy content (by volume) of the alternative fuels, this range reduction is only about 26%. Further, larger LPG vehicles can carry a larger tank, and tend to maintain a range of between 300 and 400 miles. However, to allow longer range, payload is diminished due to the size and weight of the LPG tank.<sup>34</sup>

**Safety.** LPG has a higher ignition temperature than gasoline, making it safer in that respect. Furthermore, LPG must be present in greater concentrations than gasoline to ignite.<sup>35</sup> Because LPG is stored under pressure, it must be stored in heavy-duty tanks. In order to prevent failure of the fuel tank, LPG tanks must undergo rigorous testing. Further, LPG is odorless, so an odorant is added to make it detectable in air.<sup>36</sup>

**Other Issues.** There are few major issues involving LPG fuels and vehicles other than those issues relevant to all alternative fuel vehicles, such as the need to expand fueling infrastructure. However, because LPG is often derived from petroleum refining, it may do little to diminish petroleum dependence.

## Natural Gas

Natural gas is a fossil fuel produced from gas wells or as a by-product of petroleum production. Natural gas is composed of hydrocarbons, mainly methane.<sup>37</sup> It is used extensively in residences and by industry, and is therefore widely available. Because of its gaseous nature, natural gas must be stored onboard a vehicle either as

<sup>33</sup> California Energy Commission, *Liquified Petroleum Gas*.

<sup>34</sup> In the case of a passenger car, the tank usually reduces available trunk space.

<sup>35</sup> In fact, propane can ignite through a slightly wider range of concentrations (in air) than gasoline. However, the lower flammability limit for LPG is higher than gasoline, making it generally more difficult to ignite. Below this concentration, the mixture is too “lean” to ignite. Source: Alternative Fuels Data Center, *Properties of Fuels*. August 28, 2000.

<sup>36</sup> National Propane Gas Association, *Consumer Info*. [<http://www.npga.org/>.]

<sup>37</sup> The chemical formula for methane is CH<sub>4</sub>. Natural gas also contains minor amounts of ethane (C<sub>2</sub>H<sub>6</sub>), propane (C<sub>3</sub>H<sub>8</sub>), butane (C<sub>4</sub>H<sub>10</sub>) and pentane (C<sub>5</sub>H<sub>12</sub>).

compressed natural gas (CNG) or as liquefied natural gas (LNG). CNG is generally preferred for light-duty applications such as passenger cars, while both CNG and LNG are used in heavier applications, such as buses.

**Consumption.** Vehicles consumed 170 million GEG of natural gas in the United States in 2004 (mostly as CNG).<sup>38</sup> This was about 0.1% of gasoline demand, although consumption has been rising steadily over the past ten years. After propane, CNG is the second most widely used pure alternative fuel.<sup>39</sup>

Approximately 146,000 natural gas vehicles were in operation in the United States in 2004, and the number has been growing by approximately 20% per year.<sup>40</sup> These include CNG passenger cars such as the Honda Civic, Toyota Camry, and Chevrolet Cavalier, as well CNG light trucks natural gas transit buses.<sup>41</sup> In 2003, the federal government operated approximately 18,000 CNG vehicles, and 50 LNG vehicles.<sup>42</sup> In fact, the federal government consumes more CNG than all other alternative fuels combined. Nearly 90% of the federal CNG vehicles are light duty vehicles purchased to meet EPA requirements; the rest are heavy trucks and buses.

**Cost.** Using natural gas can cut fuel costs significantly, since natural gas tends to be a relatively inexpensive fuel<sup>43</sup>. The median price for one GEG of CNG ranged from \$0.89 to \$1.19,<sup>44</sup> between April 2000 and October 2002, and the price for LNG was comparable. In addition to the low cost of the fuel, natural gas is also subject to a much lower federal excise tax rate (5.4 cents per GEG<sup>45</sup>) than the gasoline excise tax rate (18.3 cents per gallon). Depending on fuel prices, natural gas vehicles can reduce annual fuel costs significantly.<sup>46</sup>

While fuel costs tend to be lower for natural gas than for gasoline, equipment costs tend to be higher. Equipping a light-duty vehicle to operate on CNG typically costs between \$4,000 and \$6,000, though some of this incremental cost may be defrayed through federal and state incentives. In addition, although there are some

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<sup>38</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

<sup>39</sup> More ethanol is consumed, but most of this is blended with conventional gasoline.

<sup>40</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 1.

<sup>41</sup> National Alternative Fuels Hotline, *Model Year 2000*.

<sup>42</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 9.

<sup>43</sup> Current high natural gas prices have made CNG less attractive as a fuel.

<sup>44</sup> Clean Cities Program, *Alternative Fuel Price Report*.

<sup>45</sup> Based on a tax rate of 48.44 cents per 1000 cubic feet of natural gas and approximately 112 cubic feet per GEG. Source: ATA Foundation, Alternative Fuels Task Force, *1998-1999 Tax Guide for Alternative Fuels*.

<sup>46</sup> Using a natural gas price of \$0.77 per GEG, and a gasoline price of \$1.20 per gallon, annual savings would be \$200 for smaller cars and \$300 for larger vehicles. However, current prices are significantly higher for both natural gas and gasoline. Source: John DeCicco, Jim Kleisch and Martin Thomas, *ACEEE's Green Book: The Environmental Guide to Cars and Trucks*, 2000.

public fueling stations, if in-home fueling is desired, a small slow-fill unit can be installed for approximately \$3,500.<sup>47</sup>

**Infrastructure.** Refueling infrastructure for CNG is more broadly available than for most alternative fuels. There are approximately 900 public CNG refueling sites and 60 LNG refueling sites in 44 states.<sup>48</sup> Again, this number is small compared to the number of gasoline refueling stations. However, with the extensive natural gas system in the United States, the CNG refueling network could be greatly expanded. Furthermore, since slow-fill refueling systems are available for home installation, consumers could fuel their vehicles overnight, and would only need to access public stations on longer trips. However, because the technology differs significantly from a gasoline pump, vehicle users or station operators would need to be trained in the use of natural gas pumps.

**Performance.** Compared to gasoline vehicles, the environmental performance of natural gas vehicles is exceptional. Particulate emissions are virtually eliminated, carbon monoxide emissions are reduced by as much as 65% to 95%, VOC emissions are reduced by up to 80%, and nitrogen oxide (NOx) emissions by as much as 30%.<sup>49</sup> Furthermore, greenhouse gas emissions are also reduced compared with gasoline vehicles.<sup>50</sup>

The key performance drawback to natural gas vehicles is their significantly shorter range. Most natural gas passenger cars can only travel 100 to 200 miles on a full tank of fuel.<sup>51</sup> This is significantly less than the range of 300 to 400 miles for most gasoline-powered passenger cars.<sup>52</sup> For this reason, natural gas vehicles have been popular for use as delivery trucks or other fleets that operate in cities or other localized areas.

**Safety.** Natural gas tends to be safer than gasoline for many reasons. First, the fuel is non-toxic, although in high gaseous concentrations it could lead to asphyxiation. Second, natural gas is more difficult to ignite than gasoline, and tends to dissipate faster due to its lower density. However, since natural gas is colorless and odorless, like LPG, an odorant is added to the fuel to make it detectable in air.<sup>53</sup>

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<sup>47</sup> California Energy Commission, *Frequently Asked Questions About Natural Gas Vehicles*. Updated March 10, 1999.

<sup>48</sup> AFDC, *Refueling Sites*.

<sup>49</sup> Hydrocarbon and nitrogen oxide emissions contribute to the formation of ground-level ozone, the main component of urban “smog.”

<sup>50</sup> California Energy Commission, *Natural Gas Vehicles: Fuel and Vehicle History and Characteristics*. Updated March 10, 1999; James S. Cannon, *Paving the Way to Natural Gas Vehicles*, 1993.

<sup>51</sup> Larger vehicles such as pickup trucks and vans can utilize larger fuel tanks by occupying some of the storage area of the vehicle.

<sup>52</sup> National Alternative Fuels Hotline, *Model Year 2000*.

<sup>53</sup> California Energy Commission, *Frequently Asked Questions About Natural Gas Vehicles*. (continued...)

A key safety concern with natural gas has to do with on-board storage. Because CNG is compressed under such high pressures, the rupture of a fuel tank would be extremely dangerous. For this reason, CNG tanks must undergo “severe abuse” tests such as collisions, fires, and even gunfire.<sup>54</sup>

**Other Issues.** Besides the environmental benefits of natural gas, another benefit is the fact that over 80% of natural gas used in the United States comes from domestic sources.<sup>55</sup> Therefore, it has been argued that natural gas vehicles can help promote energy security in this country by lowering our reliance on imported fuel. However, because natural gas is used extensively in electricity production, significant increases in its use for transportation could result in increased demand for other fuels for electricity.

## Biodiesel

Biodiesel is a synthetic diesel fuel that is produced from fatty feedstocks such as soybean oil and recycled cooking oil.<sup>56</sup> Although more expensive than conventional diesel, it has some important advantages. The most notable advantage is that because biodiesel is very similar to conventional diesel, the fuel can be used in existing diesel engines.<sup>57</sup>

**Consumption.** Currently, U.S. consumption is about 37 million gallons per year,<sup>58</sup> as compared to approximately 36 billion gallons per year of conventional diesel.<sup>59</sup> Because biodiesel can be used in existing diesel engines, there are no vehicles designed specifically for its use.

**Cost.** The most significant drawback to biodiesel is its increased cost as compared to conventional diesel. Diesel pump prices averaged between \$1.15 and \$1.50 per gallon in 2003.<sup>60</sup> At the same time, median pump prices for B20 (a blend of 20% biodiesel in conventional diesel) ranged between \$1.29 and \$1.60.<sup>61</sup> This price difference (approximately 8 to 20 cents per gallon) implies that pure biodiesel costs as much as \$1.00 more per gallon to produce. However, wholesale biodiesel prices have been dropping due to process improvements and increases in production

<sup>53</sup> (...continued)

Updated March 10, 1999.

<sup>54</sup> The Natural Gas Vehicle Coalition, *Questions and Answers about Natural Gas Vehicles* [<http://www.ngvc.org/qa.html>]. Updated March 16, 2000.

<sup>55</sup> Energy Information Administration, *Natural Gas Monthly*. October 2000.

<sup>56</sup> Biodiesel is mixture of various compounds called mono alkyl esters.

<sup>57</sup> National Biodiesel Board, *General Interest*. [<http://www.biodiesel.org>]. Updated November 10, 2000.

<sup>58</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

<sup>59</sup> *Ibid.*

<sup>60</sup> Clean Cities Program, *Alternative Fuel Price Report*.

<sup>61</sup> *Ibid.*



scale. Further, in some places, where recycled oil is used, wholesale prices of pure biodiesel may actually be lower than for conventional diesel.

Relative to other alternative fuels, there is one key cost advantage of biodiesel. It can be used in existing diesel vehicles with little or no modification. Therefore, covered EPAAct fleets — and others interested in reducing their petroleum consumption and improving their environmental performance — may use biodiesel without the capital investments necessary for other alternative fuels.

**Infrastructure.** Because biodiesel is chemically very similar to conventional diesel, it could be placed in the existing diesel distribution system with only a few modifications. Most importantly, since biodiesel is a more effective solvent than conventional diesel, it can cause deterioration of rubber and polyurethane materials (e.g. seals). Currently, most biodiesel supply involves purchase contracts by fleet owners, and delivery of biodiesel to fleet-owned dispensing sites. However, 177 biodiesel refueling stations have opened in 37 states in the past five years.<sup>62</sup>

**Performance.** Biodiesel is generally mixed with conventional diesel at the 20% level. The resulting fuel, B20, can be used in existing diesel engines with few or no engine modifications. Higher concentrations can be used, however, especially with newer equipment. The use of biodiesel (B20 or higher concentrations) leads to substantial reductions in emissions of VOCs, carbon monoxide, and particulate matter.<sup>63</sup> However, NO<sub>x</sub> emissions tend to increase with the use of biodiesel.

Other than the changes in emissions, there seems to be little, if any, difference in performance between biodiesel and conventional diesel. Payload and range remain the same, and maintenance costs may actually be decreased due to the lower sulfur content of the fuel. Some minor modifications may be necessary with concentrations above 20%, due to fact that biodiesel is a very effective solvent and can corrode engine seals.<sup>64</sup>

**Safety.** There seem to be few additional safety concerns for biodiesel. Its safety properties are consistent with conventional diesel. However, it does have one advantage over conventional diesel. Because biodiesel has a higher flash point<sup>65</sup> than conventional diesel, it is more difficult to ignite, reducing the risk of fire.<sup>66</sup>

**Other Issues.** Biodiesel currently faces two key issues. The first has to do with the tax structure for biodiesel. Because biodiesel is a renewable fuel, there has

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<sup>62</sup> AFDC, *Refueling Sites*.

<sup>63</sup> AFDC, *Biodiesel General Information*. [[http://www.eere.energy.gov/cleancities/afdc/altfuel/bio\\_benefits.html](http://www.eere.energy.gov/cleancities/afdc/altfuel/bio_benefits.html)]. Updated May 7, 2004.

<sup>64</sup> Personal conversation with Roy Truesdale, Director of Operations, National Biodiesel Board. September 25, 2000.

<sup>65</sup> The flash point is the minimum temperature at which chemical can ignite under normal conditions.

<sup>66</sup> National Biodiesel Board, *General Interest*.

been interest in creating a tax incentive similar to the ethanol tax incentive. This incentive, supporters argue, would allow biodiesel to compete and play a larger role in our fuel supply. In 2004 Congress approved the American Jobs Creation Act (P.L. 108-357). Among other provisions, the act established a tax credit of \$1.00 per gallon for the production and use of biodiesel made from agricultural products.

The second issue involves a 1998 amendment to EPAct. This amendment<sup>67</sup> grants credits to owners of covered fleets who purchase biodiesel. These credits count toward the purchase requirements for alternative fuel vehicles. Every 450 gallons of biodiesel purchased earns one credit. This allows fleet owners to meet their EPAct requirements without purchasing new vehicles and without modifying their existing fueling infrastructure. Environmentalists have charged that because the fuel is then blended at the 20% level, there is little impact on oil consumption or vehicle emissions.<sup>68</sup>

## Ethanol<sup>69</sup>

Ethanol, or ethyl alcohol, is an alcohol made by fermenting and distilling simple sugars.<sup>70</sup> Ethyl alcohol is in alcoholic beverages, and it is denatured (made unfit for human consumption) when used for fuel or industrial purposes. Although the broadest current use of fuel ethanol in the United States is as an additive in gasoline, in purer forms it can also be used as an alternative to gasoline. It is produced and consumed mostly in the Midwest, where corn — the main feedstock for ethanol production — is produced. When used as an alternative fuel, ethanol is usually blended with gasoline at a ratio of 85% ethanol to make E85. As with other alternative fuels, there are many benefits but also drawbacks associated with its use.

**Consumption.** Ethanol is the most commonly used alternative fuel, although most of this is blended at the 10% level with 90% gasoline to make E10, or “gasohol.” Including its use in gasohol, 2004 ethanol consumption was approximately 3.1 billion gallons, or 2.0 billion GEG. This corresponds to approximately 1% of annual gasoline consumption. However, E10 is not recognized by EPAct as an alternative fuel because its widespread use does not significantly diminish gasoline consumption. Consumption of E85 — which is recognized by EPAct — is relatively low. Only about 22 million GEG of E85 were consumed in 2004, although consumption has steadily increased since 1992.<sup>71</sup>

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<sup>67</sup> P.L. 105-388, section 312.

<sup>68</sup> “Committee Backs Biodiesel,” *The Oil Daily*. August 6, 1998.

<sup>69</sup> For more information on ethanol fuel, see CRS Report RL30369, *Fuel Ethanol: Background and Public Policy Issues*.

<sup>70</sup> Its chemical formula is C<sub>2</sub>H<sub>5</sub>OH.

<sup>71</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

As of 2004, there were approximately 146,000 E85 vehicles being fueled primarily by ethanol in use in the United States.<sup>72</sup> This number has been growing, but is still negligible against the total number of conventional vehicles on the road. However, many E85 vehicles can be fueled with E85, gasoline, or any mixture of the two. There are many more of these flexible fuel vehicles (FFV) than dedicated ethanol vehicles. Models of some popular production vehicles, including the Ford Explorer and Ford Taurus now have E85/gasoline flexible fuel capability standard. Other vehicles with the option of FFV capability include the Dodge Caravan, the Chevrolet Silverado pickup, and the Mercedes-Benz C240 sedan.<sup>73</sup> The Energy Information Administration estimates that approximately 4.1 million ethanol FFVs were on the road in 2003. It is expected that the vast majority of these vehicles will be fueled with gasoline. However, it is possible that the greater availability of FFVs will spur the market for ethanol fuel. In 2002, the federal government operated approximately 53,000 ethanol FFVs, although most of these are fueled with gasoline.

**Cost.** One of the key drawbacks to the use of ethanol is its cost. Per gallon, median E85 retail prices ranged from approximately \$0.84 to \$1.41<sup>74</sup> between April 2000 and October 2002. In terms of GEG, ethanol costs ranged between \$1.16 and \$1.95.<sup>75</sup> When blended with gasoline, ethanol benefits from an exemption to the motor fuels excise tax.<sup>76</sup> This benefit makes ethanol competitive with gasoline as a blending agent. In fact, when used to make E10, the exemption is a nominal 52 cents per gallon of pure ethanol. However, for neat fuels, the exemption is much less — only a nominal 6.4 cents per gallon of pure ethanol for E85.

While fuel costs are higher for E85, there is little, if any, incremental vehicle cost.<sup>77</sup> Further, ownership and maintenance costs tend to be equal for ethanol and gasoline vehicles.

**Infrastructure.** Most of the current infrastructure for the delivery of ethanol is in the form of tanker trucks used to deliver ethanol to terminals for blending with gasoline. However, there were 205 E85 refueling sites nationally as of December 2004, mostly in the Midwest, where ethanol is produced.<sup>78</sup> Since there is experience in storing and delivering ethanol, and since the fueling systems are similar to gasoline, the refueling infrastructure could expand to meet increased demand if the delivery costs were reduced.

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<sup>72</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 1.

<sup>73</sup> National Alternative Fuels Hotline, *Model Year 2005: Alternative Fuel Vehicles and Advanced Technology Vehicles Available or Nearing Completion*.

<sup>74</sup> Clean Cities Program, *Alternative Fuel Price Report*. This includes federal and state tax incentives for ethanol and ethanol-blended fuels.

<sup>75</sup> Based on 1.41 gallons of ethanol per GEG.

<sup>76</sup> 26 U.S.C. 40.

<sup>77</sup> Because ethanol is more corrosive than gasoline, some components (e.g. seals) must be replaced.

<sup>78</sup> AFDC, *Refueling Sites*.

**Performance.** Because of its lower energy content, the key performance drawback of ethanol is lower fuel economy. Fuel economy is reduced by approximately 29%, resulting in reduced range. However, this reduction in range can be mitigated somewhat by increasing fuel tank size (with the associated drawbacks of a larger tank). Another problem with ethanol is that in cold weather, an ethanol-powered vehicle may be difficult to start. For this reason, most ethanol that is used in purer forms is E85. The 15% gasoline allows for easier ignition under cold-start conditions. There are few other technical concerns over the performance of ethanol because of the relatively few modifications necessary to operate a vehicle on ethanol.

There are key environmental advantages to ethanol, as well as some drawbacks. Ethanol-powered vehicles tend to emit 30 to 50 percent less ozone-forming compounds than similar gasoline-powered vehicles, including significant reductions in carbon monoxide emissions.<sup>79</sup> In addition, ethanol tends to have a much lower content of toxic compounds such as benzene and toluene, leading to lower emissions of most toxic compounds. However, ethanol-powered vehicles tend to emit more formaldehyde and acetaldehyde,<sup>80</sup> although these emissions can be largely controlled through the use of advanced catalytic converters.<sup>81</sup>

Another key environmental advantage with ethanol is its relatively low life-cycle greenhouse gas emissions.<sup>82</sup> Ethanol-powered vehicles tend to emit lower levels of greenhouse gases than gasoline vehicles. Also, the growth process of the ethanol feedstock results in uptake of carbon dioxide, further reducing net greenhouse gas emissions. Conversely, when the raw materials and practices used to produce the feedstock and the fuel are taken into account, emissions for both fuels are increased. According to a study by Argonne National Laboratory, the use of E85 results in a 14% to 19% reduction in life-cycle greenhouse gas emissions, and with advances in technology, this reduction could be as high as 70% to 90% by 2010.<sup>83</sup> However, other studies cite lower efficiency in the ethanol fuel cycle, leading to smaller reductions in greenhouse gas emissions.<sup>84</sup>

**Safety.** Fuel ethanol tends to be safer than gasoline. At normal temperatures, E85 is less flammable than gasoline, and tends to dissipate more quickly. While an

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<sup>79</sup> California Energy Commission, *Ethanol Powered Vehicles*. Updated November 3, 1998.

<sup>80</sup> Formaldehyde and acetaldehyde are toxic compounds that, in air, can irritate tissues and mucous membranes in humans, and are characterized by EPA as possible carcinogens.

<sup>81</sup> California Energy Commission, *Ethanol Powered Vehicles*.

<sup>82</sup> Although most greenhouse gases are not regulated pollutants, environmentalists are concerned that the accumulation of these gases (such as carbon dioxide) in the atmosphere will lead to global warming.

<sup>83</sup> M. Wang, C. Saricks, and D. Santini, *Effects of Fuel Ethanol on Fuel-Cycle Energy and Greenhouse Gas Emissions*, January 1999. Argonne National Laboratory.

<sup>84</sup> Alan Kovski, "Study Defends Fuel Efficiency of Ethanol, While Another Notes Emissions of Pollutants," *The Oil Daily*, March 9, 1998. p. 6.

ethanol flame is less visible than a gasoline flame, it is still easily visible in daylight.<sup>85</sup>

**Other Issues.** The most significant issue surrounding ethanol is the exemption from the motor fuels excise tax. Because a few producers control a majority of ethanol production capacity in the United States, the exemption has been called “corporate welfare” by its opponents. Proponents of the exemption argue that it helps support farmers (through increased demand for their product), and helps compensate for added economic value from benefits to the environment, and to energy security because ethanol is produced from domestic crops.<sup>86</sup>

Because of concerns over the fact that the exemption lowers receipts to the Highway Trust Fund, an income tax credit for ethanol blending was inserted into the American Jobs Creation Act (P.L. 108-357). The act replaces the existing exemption with a tax credit paid from the general treasury, as opposed to the Highway Trust Fund.

Another key issue is the possible development of a renewable fuels standard (RFS). An RFS would require the use of a set amount or percentage of renewable fuel in gasoline. Although there are several potential fuels that could be used to meet the standard (including biodiesel), it is likely that most of the requirement would be met with ethanol (blended at the 10% level or lower). It has been argued that an RFS would promote agricultural production and lessen the need for imported oil. Critics argue that the standard would increase gasoline prices with little effect on oil imports. Legislative proposals on an RFS are discussed below in the section on “Congressional Action.”

## Methanol

Methanol, the simplest alcohol, is also called “wood alcohol.”<sup>87</sup> It is usually derived from natural gas, but can also be derived from coal or biomass. As a fuel, methanol is most often used as a blend with gasoline called M85 (85% methanol, 15% gasoline), although the fuel can also be used in an almost pure (neat) form called M100. In addition to general transportation, Indianapolis-type race cars use methanol exclusively. As a motor fuel it has many benefits, but also many drawbacks.

**Consumption.** Because of its drawbacks, methanol consumption is relatively low. In 2004, 0.3 million GEG of methanol were consumed.<sup>88</sup> This corresponds to roughly 1/1000th of 1% of the approximately 133 billion gallons of gasoline demand. Methanol consumption peaked in 1996 and has decreased since.

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<sup>85</sup> Center for Transportation Research, Argonne National Laboratory, *Guidebook for Handling, Dispensing, & Storing Fuel Ethanol*.

<sup>86</sup> For more information, see CRS Report 98-435E, *Alcohol Fuels Tax Incentives*.

<sup>87</sup> Its chemical formula is CH<sub>3</sub>OH.

<sup>88</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 10.

There are few methanol-powered vehicles operating in the United States. Consistent with the decline in methanol consumption, after a peak in 1996, the number of M85 and M100 vehicles has declined. There were approximately 4,600 methanol vehicles in 2004. The federal government operated only 70 methanol-fueled vehicles in 2003.<sup>89</sup> The major automobile manufacturers have not sold methanol-powered production cars since model year 2001.<sup>90</sup>

**Cost.** A notable concern with methanol is its cost. Per GEG, methanol tends to be more expensive than gasoline. As of January 1, 2000, the price for methanol was between \$0.95 and \$1.20 per gallon.<sup>91</sup> However, due to the lower energy content of methanol, the fuel cost roughly \$1.73 to \$2.10 per GEG.<sup>92</sup>

In addition to the fuel cost, incremental vehicle cost is higher with the use of methanol. The incremental cost for the purchase of a methanol-fueled vehicle (or the conversion of an existing gasoline-fueled vehicle) can range from \$500 to \$2,000, though some of this incremental cost currently may be defrayed by purchase incentives. The most notable part of the incremental cost is replacing parts (such as certain seals) that may be corroded by alcohol.

**Infrastructure.** Another barrier to the wide use of methanol as a motor fuel is the lack of fueling infrastructure. While there were a few public methanol refueling stations, these stations have closed in recent years. Currently, the Department of Energy does not list any public refueling sites for methanol.<sup>93</sup> This lack of infrastructure makes it difficult for the methanol vehicle market to expand. In fact, due to lack of demand, methanol infrastructure has declined in the past few years. However, existing gasoline tanks and pumping equipment could be readily converted to store and deliver methanol, and vehicle users would experience little difference between a methanol pump and a gasoline pump.

Because methanol can be produced from natural gas and petroleum, a raw material shortage would be unlikely if methanol consumption increased. However, in terms of delivery to stations, most methanol is transported by tanker truck from the methanol plant.<sup>94</sup> This delivery method tends to be less flexible and more costly compared to the existing gasoline infrastructure, which relies primarily on pipeline delivery. Methanol cannot travel through pipelines due to its physical properties.

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<sup>89</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 9.

<sup>90</sup> National Alternative Fuels Hotline, *Model Year 2002*.

<sup>91</sup> GAO, *Limited Progress*. Appendix 1. Because of methanol's limited use, current price data are not readily available.

<sup>92</sup> Based on 1.77 gallons of M85 per GEG.

<sup>93</sup> AFDC, *Refueling Sites*.

<sup>94</sup> In contrast, gasoline is usually shipped in pipelines from the refinery to a distribution terminal, where tanker trucks transport the fuel to the fueling stations. This distribution network is considerably more cost effective than relying solely on tanker trucks.

**Performance.** One of the key benefits of methanol vehicles is improved environmental performance over gasoline vehicles. M85 vehicles tend to emit 30% to 50% less ozone-forming compounds. And while formaldehyde emissions tend to be higher with methanol than gasoline, M85 vehicles would likely be able to meet new emissions standards.<sup>95</sup>

A key performance drawback with methanol vehicles is a reduction in vehicle range. Since it requires 1.77 gallons of methanol to equal the energy in 1 gallon of gasoline, range per gallon is decreased by approximately 40%. By increasing the size of the fuel tank, the loss of range can be significantly improved or even eliminated. However, a larger fuel tank would decrease fuel economy and cargo space.

**Safety.** On the whole, methanol fuel is safer than gasoline. Since methanol vapor is only slightly heavier than air, vapors disperse quickly compared to gasoline. Furthermore, methanol vapors must be more concentrated than gasoline to ignite, and methanol fires release less heat. Since methanol burns with a light blue flame, one key drawback is that in bright daylight it may be difficult to see a methanol fire, although it may be possible to add colorants to the fuel.<sup>96</sup>

**Fuel Cells.** Methanol has been touted as potential step from gasoline to hydrogen in fuel cell vehicles because the fueling infrastructure is similar to gasoline, while the fuel is much cleaner.<sup>97</sup> Fuel cells are a type of power system that generates electricity from hydrogen (or a hydrogen-bearing compound) without combustion. The chemical process is highly efficient and drastically reduces vehicle emissions.<sup>98</sup> For more information on fuel cells, see CRS Report RL30484, *Advanced Vehicle Technologies: Energy, Environment, and Development Issues*.

Another potential advantage of methanol is that it can be derived from biomass waste products. Research is ongoing, and there have been a few, small-scale demonstration projects at landfills. If methanol is produced instead from fossil fuel resources, it may be less likely to promote energy independence.

## Electricity<sup>99</sup>

An electric vehicle (EV) is powered by an electric motor, as opposed to an internal combustion engine. Energy is supplied to the motor by a set of rechargeable batteries. When the vehicle is not being used, these batteries are recharged.

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<sup>95</sup> California Energy Commission, *Questions and Answers About M85 and Flexible Fuel Vehicles*. Updated December 14, 1998.

<sup>96</sup> Environmental Protection Agency, *Fact Sheet OMS-8: Methanol Fuels and Fire Safety*. August 1994.

<sup>97</sup> Vanessa Houlder, "Big push to reduce fuel emission problems," *Financial Times*. September 21, 2000. p. 5.

<sup>98</sup> If pure hydrogen is used, the only emissions would be water vapor.

<sup>99</sup> For more information on electric vehicles, hybrid electric vehicles, and fuel cell vehicles, see CRS Report RL30484, *Advanced Vehicle Technologies: Energy, Environment, and Development Issues*.

Because no fuel is burned, there are no emissions from the vehicle, making it a zero emissions vehicle (ZEV). However, there are emissions from electricity production associated with electric vehicles. When the entire fuel cycle is considered, pollutant emissions from EVs are still low relative to gasoline vehicles. Like other AFVs, however, there are key cost and performance drawbacks associated with these vehicles.

**Consumption.** Approximately 12 million GEG of electric fuel were consumed in the United States in 2004 by approximately 56,000 electric vehicles.<sup>100</sup> Most of these vehicles were located in California, and several models were available exclusively in that state. One of the most popular EVs was the General Motors (GM) EV1, although GM has discontinued production of the vehicle and has recalled all of its leases, due to limited consumer acceptance of the vehicles. Other manufacturers have also discontinued production of their electric vehicles<sup>101</sup> The federal government operated approximately 1,300 electric vehicles in 2003.<sup>102</sup>

**Cost.** Electric fuel is considerably less expensive than using gasoline, about 2.5 to 3.3 cents per mile, as opposed to 4 to 6 cents per mile for a gasoline vehicle.<sup>103</sup> Despite the fuel cost advantages, a major drawback with EVs is the incremental vehicle purchase cost, which can be as much as \$20,000. Most of this cost is related to the batteries, which are very expensive to produce.<sup>104</sup>

**Infrastructure.** There are very few electric recharging sites in the United States. Currently, there are about 700 recharging sites, mostly in California.<sup>105</sup> With the extensive nature of the electricity infrastructure in the United States, there are few technical barriers to expanding EV recharging sites. However, with existing technology, only a few vehicles can access a single charger in one day, as opposed to a gasoline pump which can serve a new vehicle every few minutes.

**Performance.** The environmental performance of EVs is very good. When the entire fuel cycle is considered, electric vehicles produce low overall levels of

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<sup>100</sup> EIA, *Alternatives to Traditional Transportation Fuels*, Tables 1 and 10. These vehicles are light- and heavy-duty highway vehicles. Golf carts are another popular application for electric vehicles, and there are many of these in operation in the United States, especially in smaller communities.

<sup>101</sup> National Alternative Fuels Hotline, *Model Year 2000*.

<sup>102</sup> EIA, *Alternatives to Traditional Transportation Fuels*. Table 9.

<sup>103</sup> Because of the vast differences between electric and conventional vehicles, cents per mile are used to discuss fuel cost, as opposed to dollars per GEG. In this case, it was assumed that electricity was 10 cents per kilowatt-hour (kWh), an electric vehicle achieved between 3 and 4 miles per kWh, gasoline cost \$1.20 per gallon, and a gasoline vehicle achieved between 20 and 30 miles per gallon. Currently, electricity prices are somewhat lower than 10 cents per kWh, while gasoline prices are above \$1.20 per gallon.

<sup>104</sup> This is based on suggested retail prices for the EV1 and the Chevrolet Cavalier, a similar gasoline vehicle.

<sup>105</sup> AFDC, *Refueling Sites*.



toxic and ozone-forming pollutants.<sup>106</sup> Depending on the fuel mix for local electric power generation, overall emissions can be decreased by 90% or more as compared to gasoline vehicles.<sup>107</sup>

A major performance drawback of EVs is their relatively short range. On a full charge, an electric vehicle can travel between 50 and 130 miles, as opposed to a range of 300 to 400 miles with a conventional vehicle.<sup>108</sup> Another drawback is that fueling an electric vehicle takes between 3 and 8 hours, as opposed to a few minutes for a conventional vehicle.<sup>109</sup>

**Safety.** Few additional safety issues are associated with electric vehicles. Because no chemicals are transferred during fueling, there is no risk of spillage or inhalation, and with existing recharging systems, electric shocks are unlikely. In the event of an accident, there is no combustible fuel so there is no danger of fire or explosion. However, because of the acid contained in some types of batteries, there could be concern over acid leaks if batteries were to rupture in a collision. Further, because of the higher current in the electrical systems, there is increased potential for shock to emergency responders in the case of a collision.

**Fuel Cell and Hybrid Vehicles.** While battery-powered electric vehicles tend to be very expensive, and have many other drawbacks, there is growing interest in fuel cell and hybrid electric vehicles. Research into batteries, electric drivetrains, and lightweight materials will play a key role in the development of EVs, as well as both hybrid and fuel cell vehicle technology. For a more detailed discussion of fuel cell and hybrid technologies, see CRS Report RL30484, *Advanced Vehicle Technologies: Energy, Environment, and Development Issues*.

**Fuel Cell Vehicles.** Unlike a conventional vehicle, a fuel cell vehicle uses chemical reaction (as opposed to combustion) to produce electricity to power an electric motor. Unlike a battery-powered EV, fuel cell vehicles have a fuel tank, eliminating the long recharging time. These systems can be very efficient, although the technology is far from commercialization. A few auto manufacturers have offered a small number of fuel cell vehicles for lease in model year 2004, and several other manufacturers plan to introduce fuel cell vehicles in the next few years. It is expected that these vehicles will be leased to corporations and that the lease costs will be relatively high (compared to conventional vehicles).

**Hybrid Electric Vehicles.** A hybrid electric vehicle combines an electric motor with a gasoline or diesel engine. This combination leads to very high fuel efficiency and low emissions while avoiding some of the problems associated with pure electric vehicles. Most hybrids operate solely on conventional fuel, with the engine providing power to the wheels and to an electric generator simultaneously.

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<sup>106</sup> The fuel mix plays a key role in the overall fuel-cycle emissions for electric vehicles because power plant emissions can vary greatly depending on the fuel used for generation.

<sup>107</sup> California Energy Commission, *Questions & Answers About Electric Vehicles*.

<sup>108</sup> Alternative Fuels Data Center, *Model Year 2000*.

<sup>109</sup> California Energy Commission, *Questions & Answers About Electric Vehicles*.

Therefore, hybrids can be fueled as quickly and conveniently as conventional vehicles, while achieving even longer ranges.

A total of seven production vehicles are expected to be available by early 2005, and most of the major car companies plan to have hybrid models available in the next few years.<sup>110</sup> Although hybrid electric vehicles are not considered AFVs for compliance with EPA's requirements (because they utilize conventional fuel), they do qualify for a Clean Fuel Vehicle Tax Deduction. The environmental performance of hybrids has led to congressional interest in larger incentives to promote their commercialization.<sup>111</sup>

## Hydrogen

Due to its presence in water, hydrogen is abundant, although it does not appear in pure form in any significant quantity.<sup>112</sup> The hydrogen in water can be separated from oxygen through a process called hydrolysis.<sup>113</sup> Other key hydrogen sources are fossil fuels and other hydrocarbons. Hydrogen fuel is of interest because it can be used in a zero-emission fuel cell. Because hydrogen fuel can be stored in sufficient quantity onboard the vehicle, fuel cell-powered electric vehicles do not face some of the range and fueling limitations as battery-powered electric vehicles.

Currently, no production vehicles are powered by pure hydrogen, although all of the major domestic and foreign automobile manufacturers are researching hydrogen fuel cells, and a few have introduced a limited number of hydrogen fuel cell vehicles for lease in model year 2004. However, it is possible that the first publicly available fuel cell vehicles will be operated on a liquid fuel such as gasoline or methanol, because these fuels are much easier to deliver and are more readily available at present (see above section on methanol).

In his January 28, 2003, State of the Union Address, President Bush announced a new five-year, \$720 million research and development initiative for hydrogen fuel. This initiative is intended to complement the FreedomCAR initiative, which focuses on the development of fuel cell vehicles. The Administration's plan would dedicate a total of \$1.8 billion over five years for hydrogen and fuel cells. Among other provisions, the conference committee report on H.R. 6 (the comprehensive energy bill in the 108<sup>th</sup> Congress) would have authorized a total of \$2.15 billion for the initiatives. The Administration requested \$257 million in FY2004 for these initiatives. However, while Congress approved an increase of \$50 million over

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<sup>110</sup> Gregg Easterbrook, "Hybrid Vigor," *The Atlantic Monthly*. November 2000. p. 5.

<sup>111</sup> Several bills in the 108<sup>th</sup> Congress would provide tax credits for the purchase of hybrids, although none of these bills passed their respective committees. See section below on Congressional Action.

<sup>112</sup> The chemical formula for hydrogen gas is H<sub>2</sub>.

<sup>113</sup> The chemical formula for water is H<sub>2</sub>O.

FY2003 levels, this was still \$23 million below the requested level.<sup>114</sup> For FY2005, Congress appropriated \$261 million, slightly below the Administration's request.<sup>115</sup>

**Consumption.** Currently, hydrogen fuel consumption is very low. In fact, the Energy Information Administration does not report U.S. hydrogen consumption in its Alternatives to Traditional Transportation Fuels.

**Cost.** Storage and delivery of hydrogen are complicated because at standard temperatures and pressures, hydrogen gas has a very low density. Therefore, the fuel must be compressed, stored in liquid form, or stored in some other manner (e.g., bonded with other chemicals or stored in a container with complex geometry). Currently, each of these storage options has its drawbacks, which can include safety, cost, and the ability to store enough hydrogen onboard the vehicle to provide acceptable range.

In addition to the increased cost of storing hydrogen fuel on a vehicle, other system components are currently prohibitively expensive. It is estimated that a fuel cell for passenger car applications is roughly 10 times more expensive than a conventional engine at today's costs. However, it is expected that with technological advances and the use of mass production the price of a fuel cell system will decrease in the future.

Currently, because hydrogen is produced in very low quantities for fuel use (it is used most as a process chemical in petroleum refining), it is considerably more expensive than gasoline at current prices. Further, because the infrastructure to deliver hydrogen is vastly different from petroleum infrastructure, expanding hydrogen delivery will also be complicated, and likely expensive.

**Infrastructure.** There is very little infrastructure to deliver hydrogen fuel, and most current facilities are in place to serve small demonstration and test fleets. As was stated above, expanding hydrogen infrastructure will likely be expensive.

**Performance.** The potential environmental performance of hydrogen fuel could exceed all other alternative fuels. Fuel cells are significantly more efficient than gasoline engines, and the only emissions from hydrogen fuel cells are heat and water vapor. However, the fuel cycle emissions from the production of hydrogen fuel could diminish its environmental performance, depending on the primary fuel used. For example, if produced from solar energy, the total fuel cycle pollutant and greenhouse gas emissions could be very low or even zero. But if fossil fuels are burned or reformed to generate hydrogen, depending on whether emissions are captured, total emissions could equal or even exceed those of efficient gasoline and diesel vehicles. Therefore, the ultimate feedstock for hydrogen production has become a significant policy concern.

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<sup>114</sup> P.L. 108-108 and P.L. 108-137. For more information on these initiatives see CRS Report RS21442, *Hydrogen and Fuel Cell Vehicle R&D: FreedomCAR and the President's Hydrogen Fuel Initiative*.

<sup>115</sup> P.L. 108-447; H.Rept. 108-792.

**Safety.** There are some key safety concerns and some likely benefits from the use of hydrogen fuel. Because of its low density in air, hydrogen fuel is likely to dissipate quickly in an open area, reducing safety concerns. Further, hydrogen rises, which may make it less likely than other fuels to lead to asphyxiation if released in an enclosed area. However, when hydrogen does burn, the flame is transparent. Further, hydrogen is highly reactive, and in the presence of a leak the fuel can be ignited with a small spark of static electricity. Other concerns include the safety of high-pressure or low-temperature onboard fuel storage, the safety of hydrogen stations in populated areas, and the need to train first responders about hydrogen safety.

## Coal-Derived Liquid Fuels

Although EPA recognizes coal-derived fuels as alternative fuels, these fuels have seen little commercial success. This is largely due to their high production costs and poor environmental performance.<sup>116</sup> However, research to reduce costs and improve environmental performance is ongoing, mostly through support of the Department of Energy.<sup>117</sup> A potential advantage of coal-derived fuels is that the feedstock is an abundant domestic resource.

## Conclusions

Alternative fuels have reached varying levels of commercial success, although currently none are able to compete with conventional fuels. LPG and natural gas fuels and vehicles have been successfully commercialized, and are widely used in both private and public fleets. Ethanol is a common additive in gasoline, but is used sparsely as an alternative fuel. Other fuels, such as methanol and electricity have had less commercial success, but may play a key role in the future of transportation.

The degree to which various alternative fuels have been used has been a result of economic factors, as well as government tax policies and regulatory mandates. Further, the performance characteristics of the fuels have also played a major role.

In general, there are potential energy security benefits to alternative fuels, as most alternative fuels can be derived from domestic sources. Further possible benefits include lower emissions of toxic pollutants, ozone-forming pollutants, and greenhouse gases. However, performance and cost are key barriers to consumer acceptance. Without considerable advances in alternative fuel and vehicle technology, or significant petroleum price increases, it is unlikely that any fuel or fuels will replace petroleum-based fuels in the near future.

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<sup>116</sup> In fact, while the fuels themselves may result in lower vehicle emissions, the processes for converting coal to liquid fuel tends to lead to high pollutant emissions.

<sup>117</sup> Nicholas P. Chowey, "Coal Conversion Keeps Itself Relevant," *Chemical Engineering*, September 1998. p. 35.

## Congressional Action

Recent policy debate has focused on American energy security. Because of this, discussion has turned to alternative fuels. Proponents argue that expanding alternative fuel tax credits and other incentives would promote improved air quality and energy security. Opponents argue that alternative fuel programs could lead to “corporate welfare” and that there are less expensive ways to reduce pollution and cut fuel consumption, such as efficiency improvements and conservation. For example, an increase in fuel economy of one mile per gallon across all passenger vehicles in the United States could cut petroleum consumption more than all alternative fuels and replacement fuels<sup>118</sup> combined.<sup>119</sup>

The Bush Administration’s National Energy Policy<sup>120</sup> supports an increased role for alternative fuels, as did several bills in the 108<sup>th</sup> Congress. Provisions in various bills would have provided tax credits for the purchase of alternative fuel and hybrid vehicles, and would have expanded the existing electric vehicle tax credit. Further, some bills would have expanded the existing tax credits and deductions for the installation of alternative fuel refueling infrastructure. Some bills also would have provided per-gallon tax credits for the retail sale of alternative fuels, and some bills would have allowed states to exempt alternative fuel and/or hybrid vehicles from high occupancy vehicle (HOV) restrictions. Finally, some bills would have provided grants to schools, municipalities, and/or transit systems for the purchase of alternative fuel vehicles, refueling infrastructure and/or fuel.

Most notably, the Energy Policy Act of 2003 (H.R. 6) contained several provisions on alternative fuels. The conference report (H.Rept. 108-375) would have required the use of 5.0 billion gallons of renewable fuel in gasoline by 2012 (renewable fuels standard). Further, the bill would have authorized the \$2.15 billion over five years for hydrogen and fuel cell research and development. The bill also would have provided a tax credit for the purchase of fuel cell vehicles. Finally, the bill would have modified the way vehicle purchase credits are generated under EPAct. The House approved the conference report on November 18, 2003. On November 21, 2003, a cloture motion on the bill was rejected in the Senate. It is likely that a similar bill will be introduced in the 109<sup>th</sup> Congress.

Another key piece alternative fuel legislation in the 108<sup>th</sup> Congress was the CLEAR ACT (H.R. 1054 and S. 505). These bills would have expanded the existing EV tax credit and infrastructure deduction, and created new credits for alternative fuel vehicles and hybrids. Further, the bills would have established a tax credit for the retail sale of alternative fuel.<sup>121</sup>

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<sup>118</sup> Replacement fuels include blending agents such as ethanol in E10, that are used in gasoline but do not qualify as alternative fuels.

<sup>119</sup> Source: CRS analysis of data from the Department of Energy.

<sup>120</sup> National Energy Policy Development Group, *National Energy Policy*. May 2001.

<sup>121</sup> For a detailed discussion of the CLEAR ACT, see CRS Report RS21277, *Alternative Fuel Vehicle Tax Incentives and the CLEAR ACT*.

Most notably, on October 22, 2004, the American Jobs Creation Act was signed into law (P.L. 108-357, H.R. 4520). Among other provisions, this act replaced the existing tax exemption for ethanol-blended fuel with a tax credit. In addition, it established a tax credit for the production and sale of biodiesel fuel.

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